

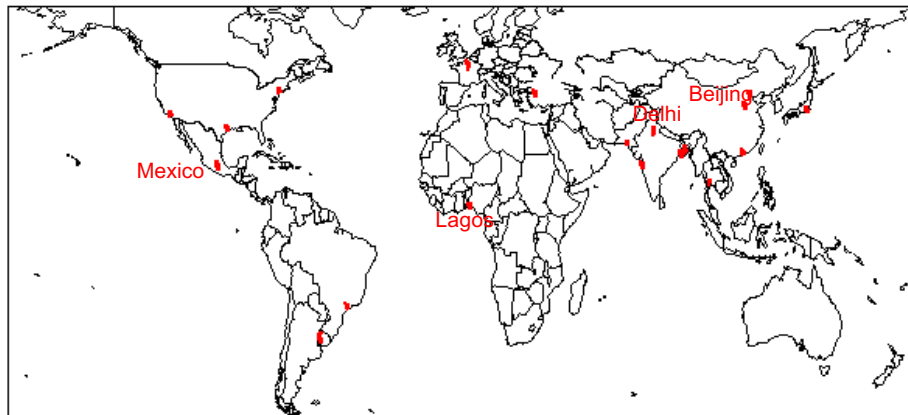
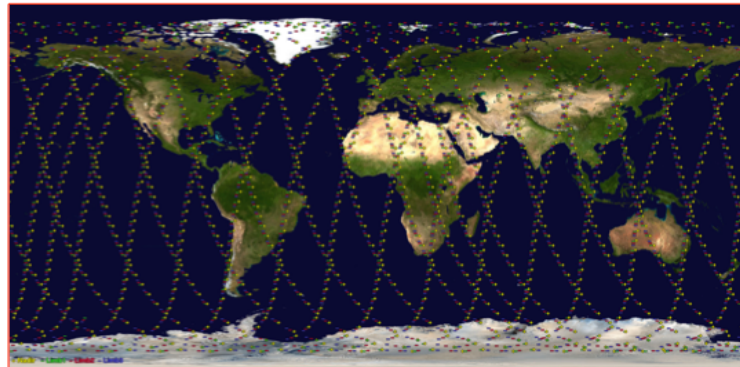
# Pollution over megacity regions from the Tropospheric Emission Spectrometer (TES)

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Kevin Bowman<sup>2</sup>, Ming Luo<sup>2</sup>, Rick Pernak<sup>1</sup>, Jennifer Hegarty<sup>1</sup>,  
Zitely Tzompa-Sosa<sup>3</sup>, Jeana Mascio<sup>1</sup>,  
Mark Shephard<sup>4</sup>

1. Atmospheric and Environmental Research (AER)
2. Jet Propulsion Laboratory (JPL)
3. Colorado State University
4. Environment and Climate Change Canada

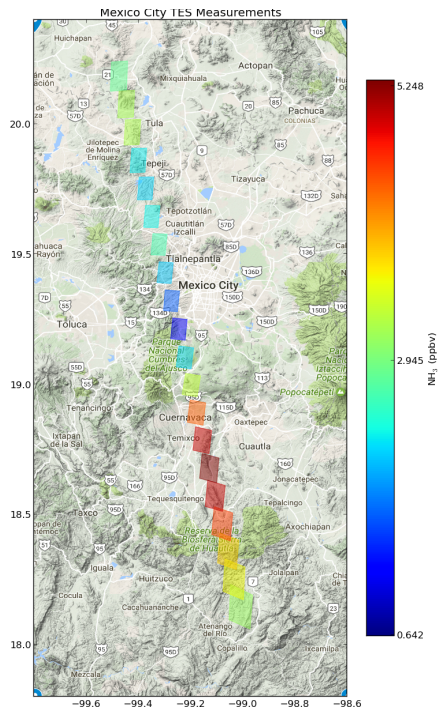
# TES measures AQ around the world

- **July 2004:** TES launched on AURA satellite
  - Main targets: O<sub>3</sub> and CO
  - Other species added:
    - CH<sub>4</sub>, CO<sub>2</sub>, **NH<sub>3</sub>**, **CH<sub>3</sub>OH**, **HCOOH**, **PAN**
  - Global surveys carried out through 2010
    - Observations ~ 182 km apart
  - Also a number of more closely spaced special observations
- 
- **January 2013:** megacity observations start
  - simultaneous closely spaced observations of multiple trace gases (~ 12 km apart)
  - quantify urban pollution production, transformation and export.

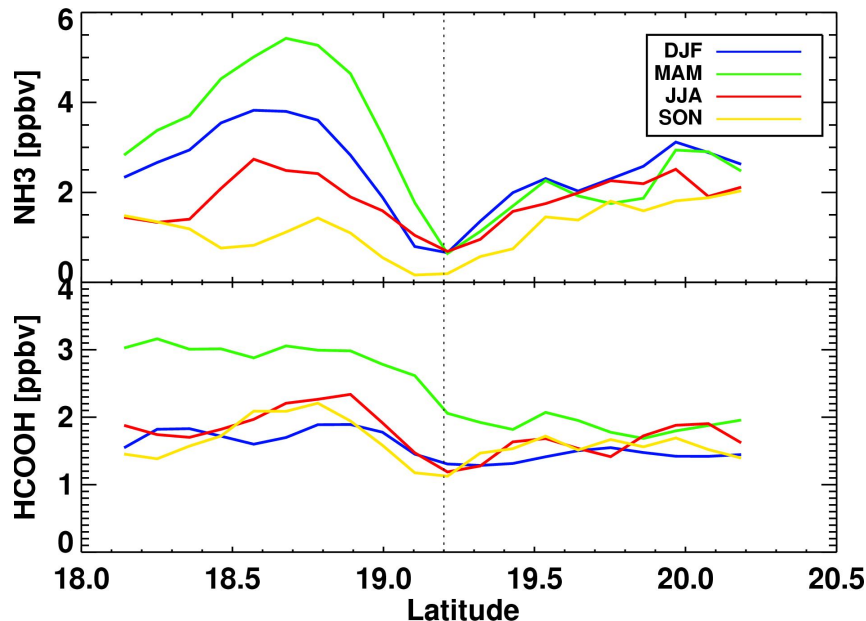


# NH<sub>3</sub> and HCOOH near Mexico City

## TES MAM NH<sub>3</sub> transect



## TES Seasonal means



**TES NH<sub>3</sub> peaks to the south, especially in DJF and MAM**  
**TES HCOOH peaks in same region in MAM**



**Fire source?**

**Focus on air quality near the surface:**

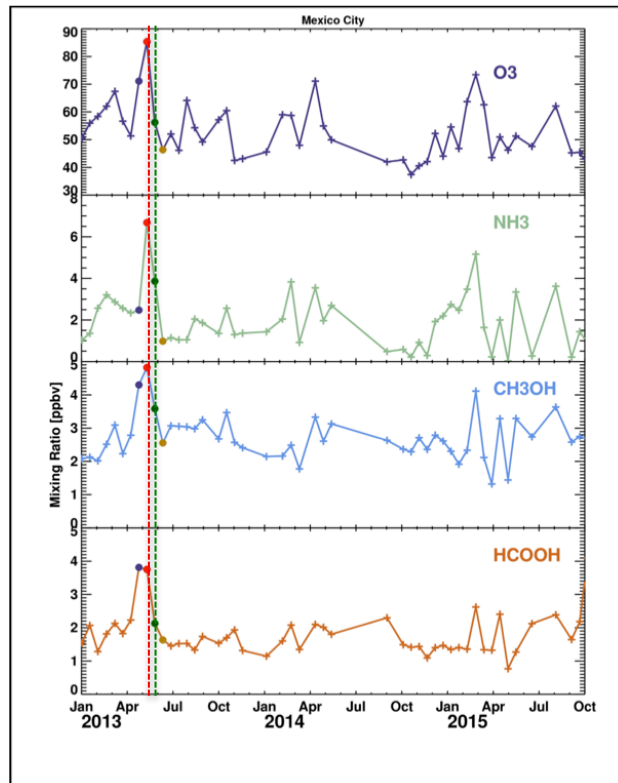
➔ will use means of TES data over the first two or three layers above the surface

# Biomass burning in Mexico

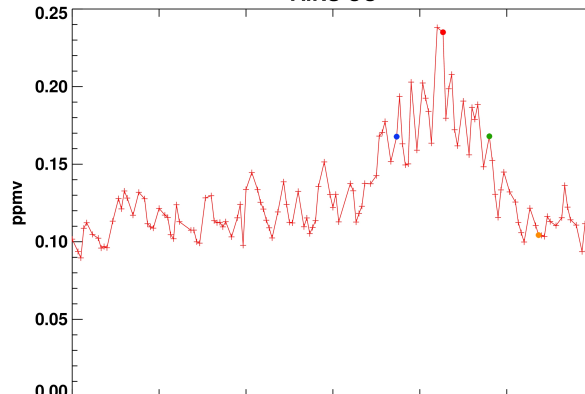
## TES transect means

May 9

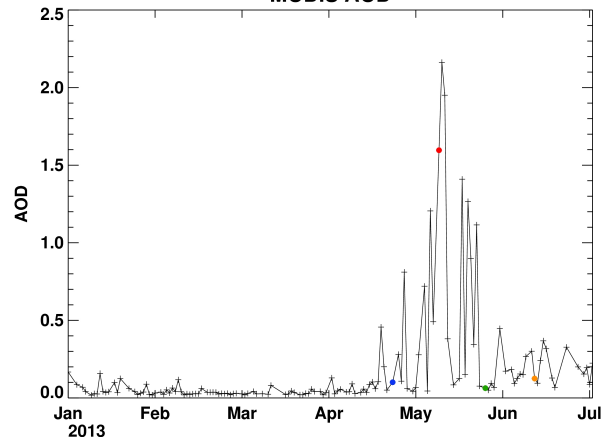
May 25



## AIRS CO



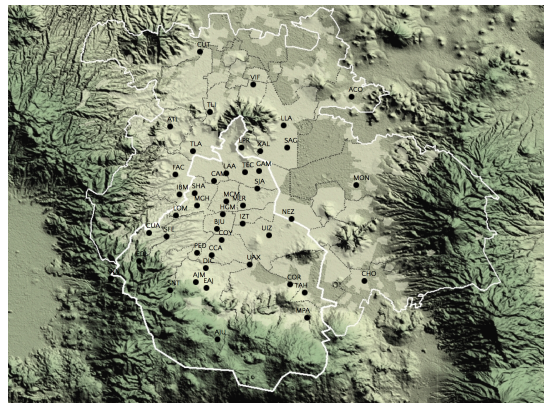
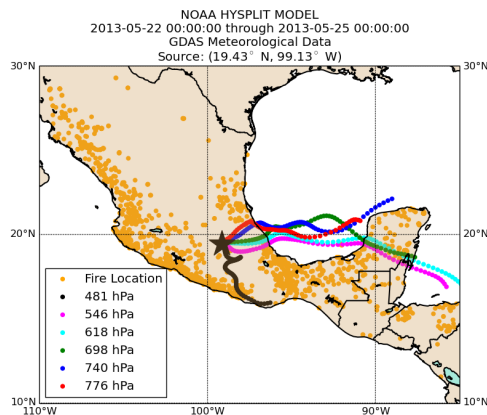
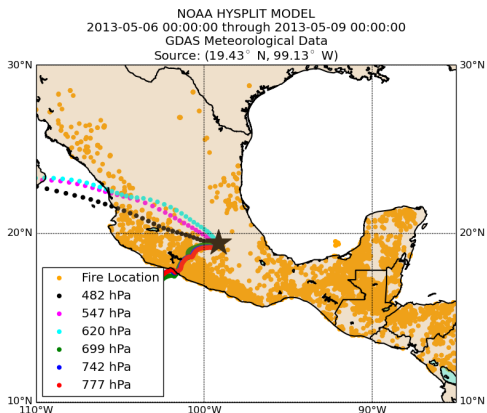
## MODIS AOD



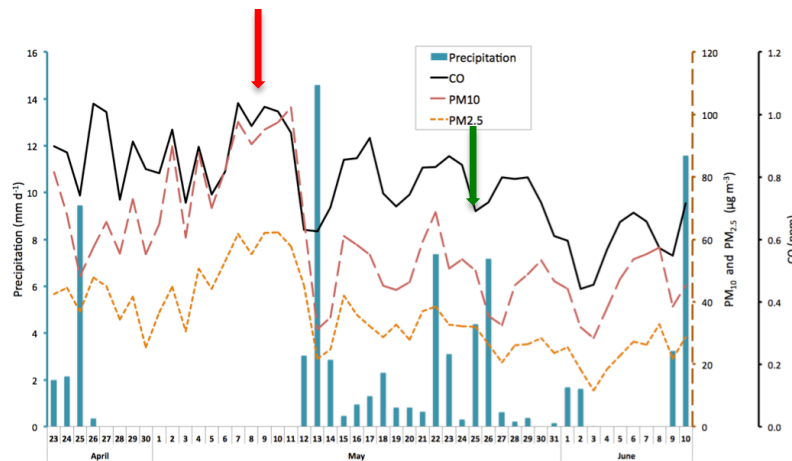
- Concomitant biomass burning products from TES (methanol, formic acid, ammonia) also point to air quality impacted by biomass burning
- Contrasting days in spring 2013 provide a case study of TES sensitivity

# Possible BB sources

## HYSPLOT four day back trajectories



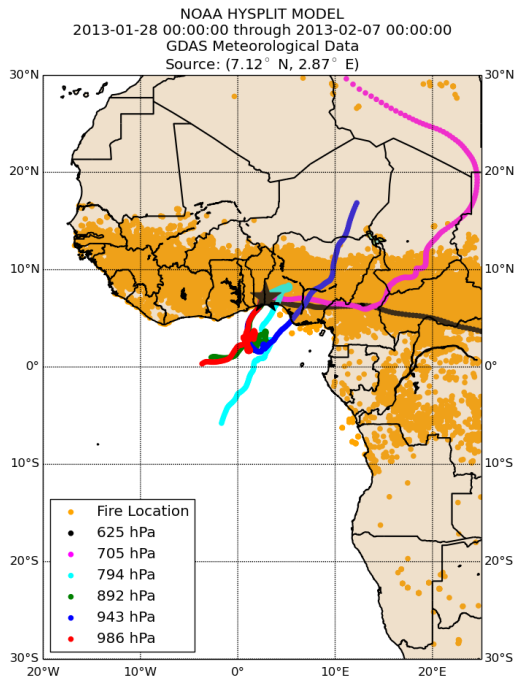
SIMAT stations in the MCMA



Daily means from SIMAT stations

# Western Africa- Lagos

**Western Africa has one of the strongest biomass burning seasons (December-March) on Earth**

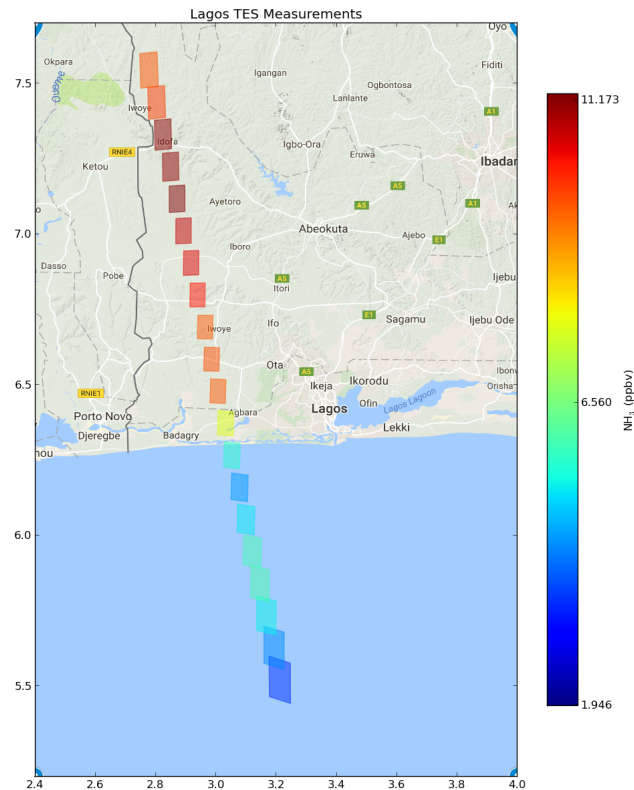


## Pollution sources

- Biomass burning
- Petrochemical
- Two-stroke engines
- Generators
- Trash burning
- Traffic

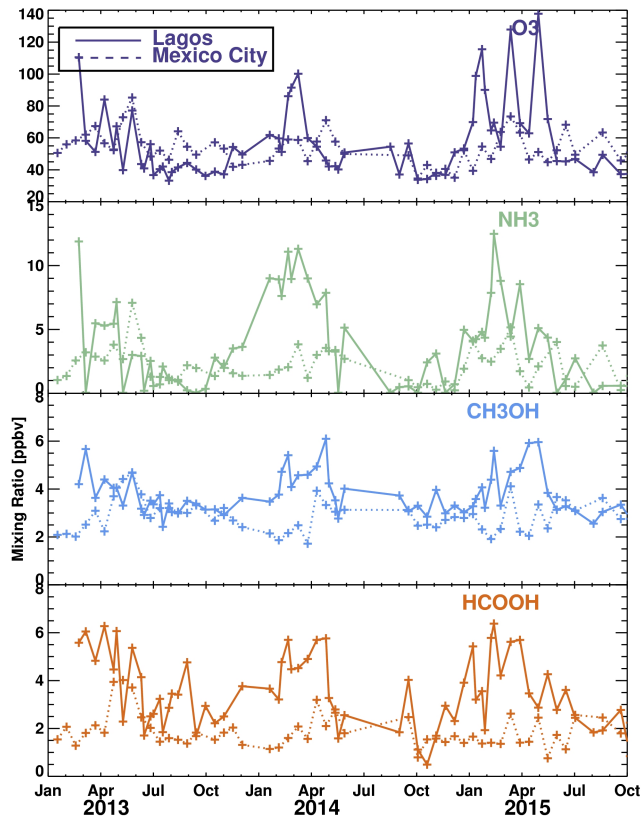
**Sea breezes play important role**

**2015 El Nino may have also been influential**



# High pollution in DJF

## TES



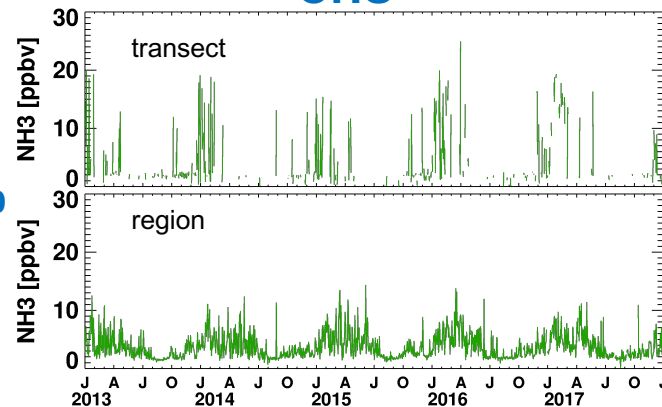
TES data suggest  
burning is an  
important driver of  
pollution in Lagos

... and that pollution  
is higher than in  
Mexico City

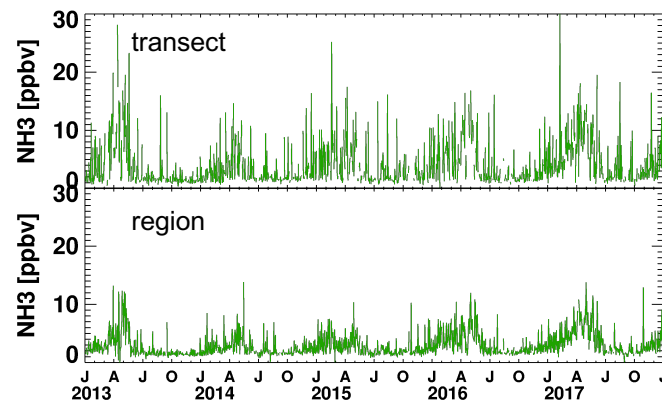
CrIS data show more  
persistent elevated  
NH<sub>3</sub> in Lagos

## CrIS

### Lagos

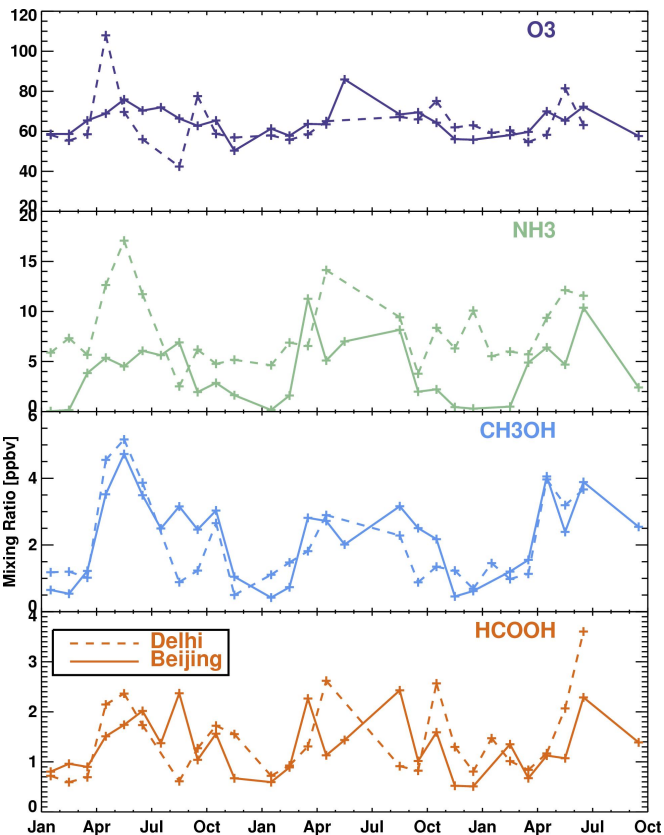


### Mexico City

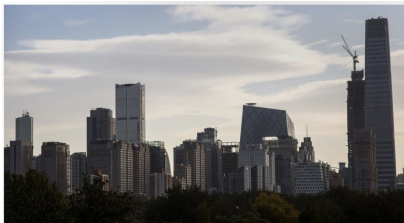


# A Tale of Two Cities

TES



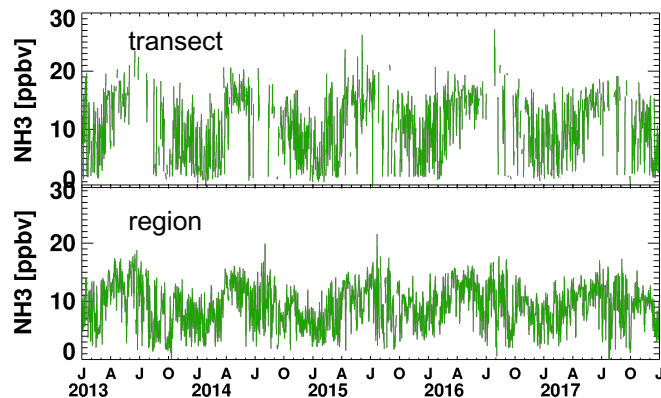
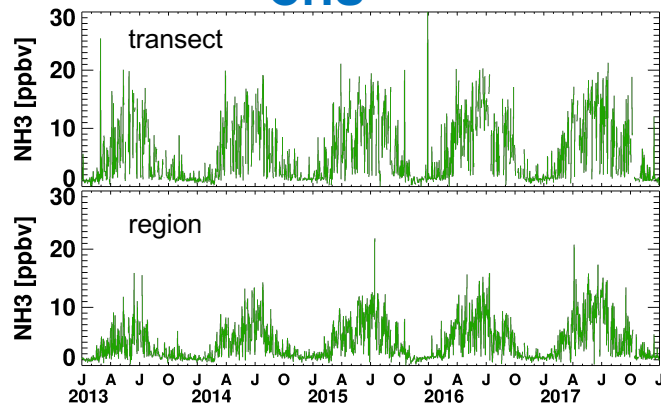
Beijing



Delhi



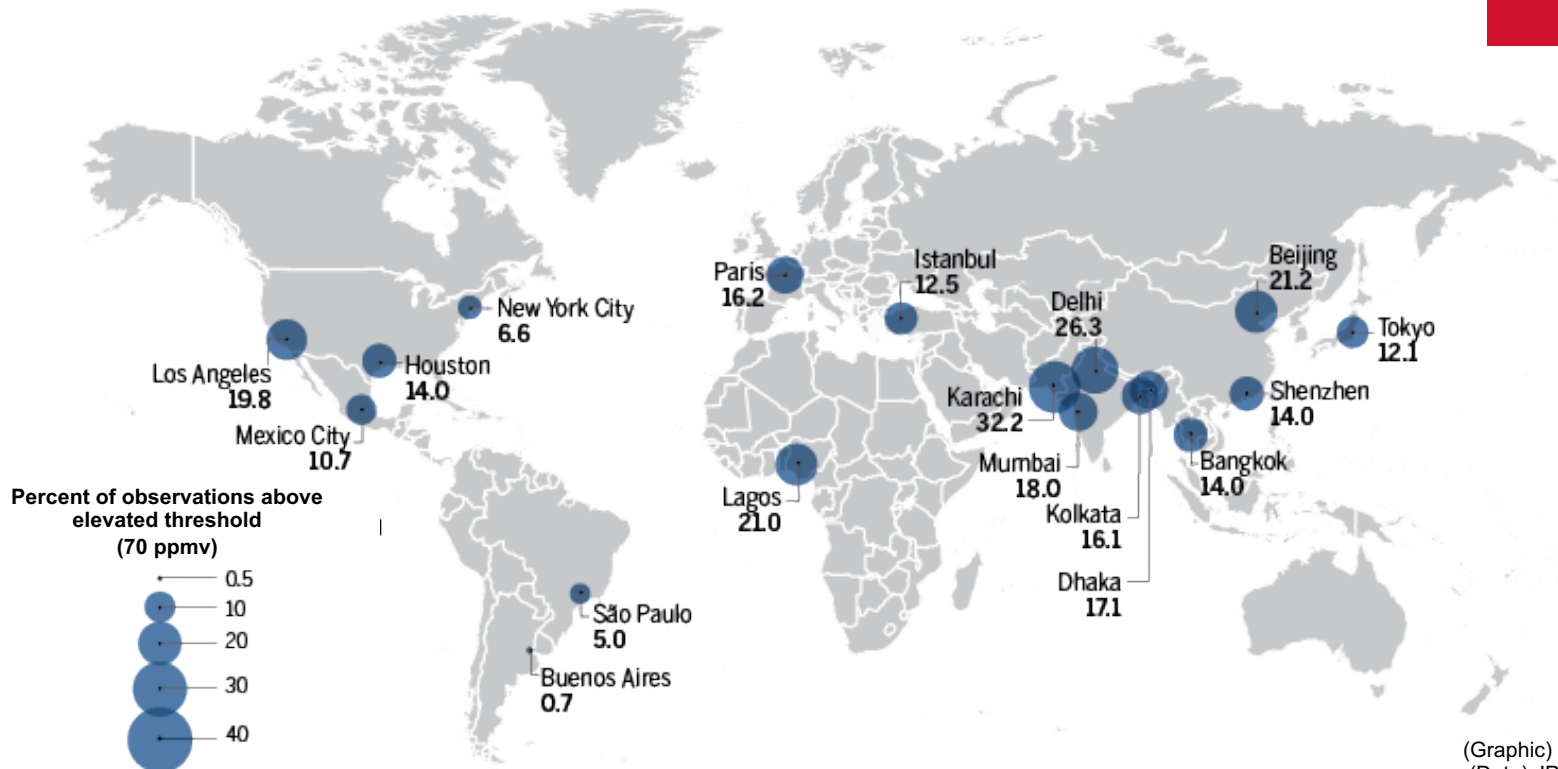
CrIS



# Global view – O<sub>3</sub>

Science  
AAAS

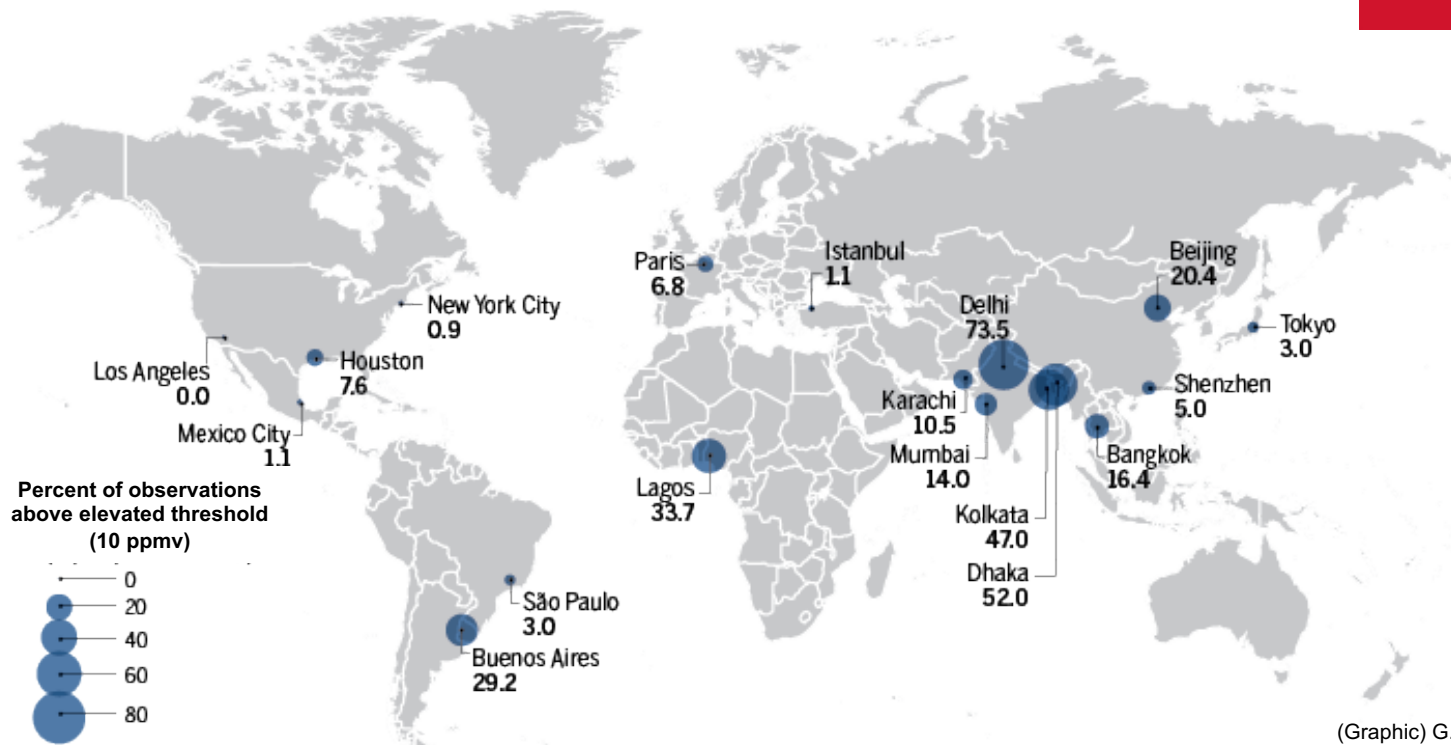
## Ozone levels



(Graphic) G. Grullón/Science;  
(Data) JPL TES Science Team

# Global view – NH<sub>3</sub>

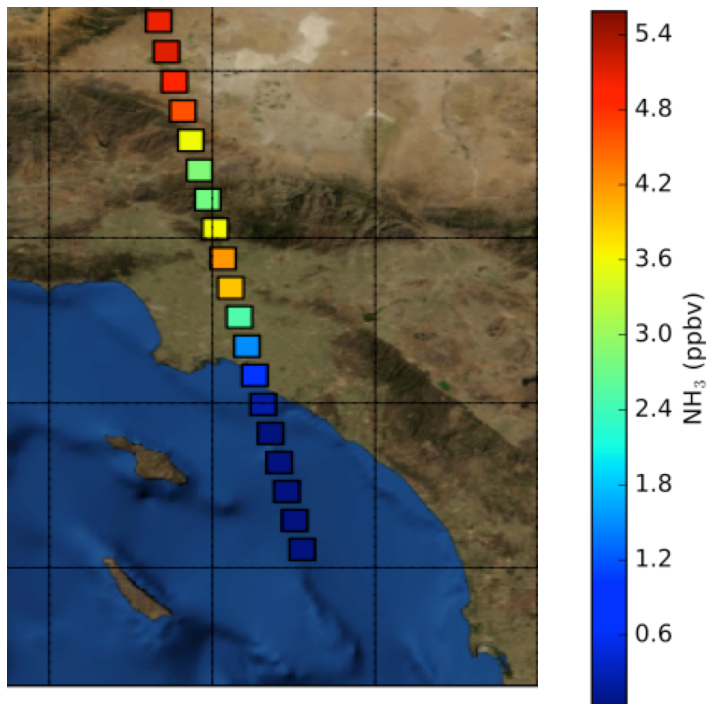
## Ammonia levels



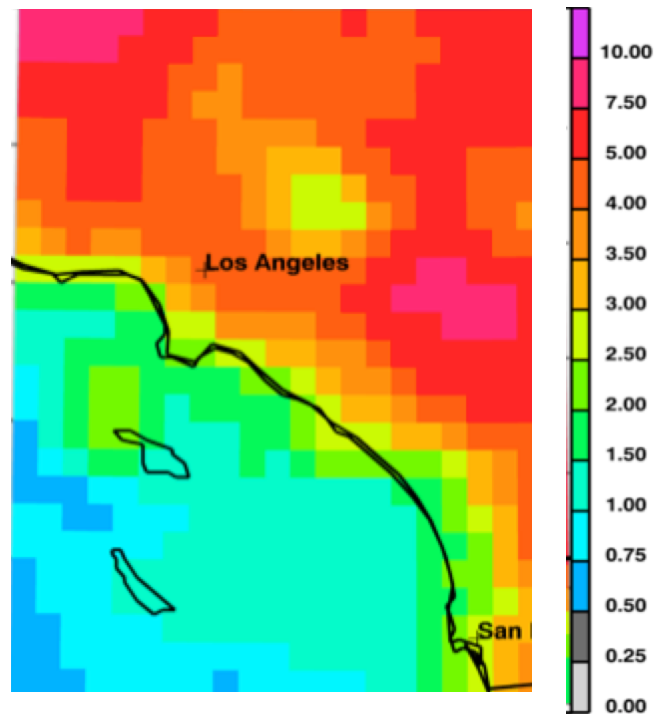


# And now CrIS $\text{NH}_3$

TES (JJA average)



CrIS (July mean)



# Summary

- TES has processed data from January 2013 to March 2016 over 19 megacities
- Data are closely spaced (12 km) and are taken approximately every two weeks
- Species measured: O<sub>3</sub>, CH<sub>4</sub>, NH<sub>3</sub>, CH<sub>3</sub>OH, HCOOH, HDO, PAN, CO<sub>2</sub>
- Data point to influences of biomass burning and other pollution sources
- Also show different chemistry regimes in different cities
- Ongoing work uses the new AIRS-OMI O<sub>3</sub> product to provide context for interpreting the TES megacity measurements
- Data are available on AVDC

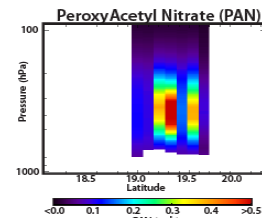
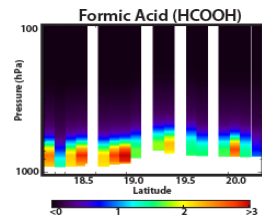
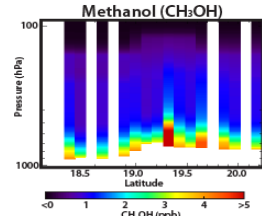
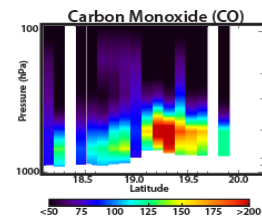
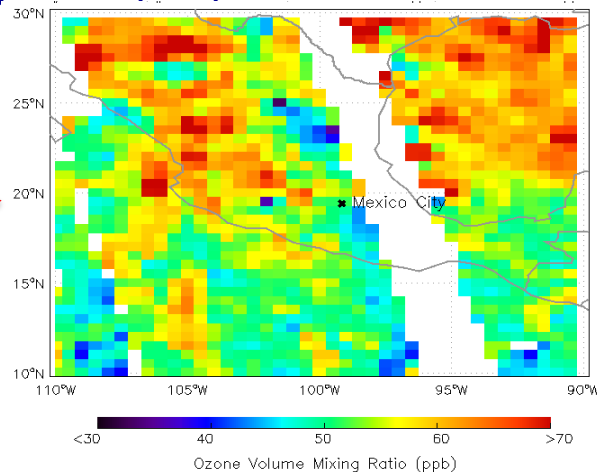
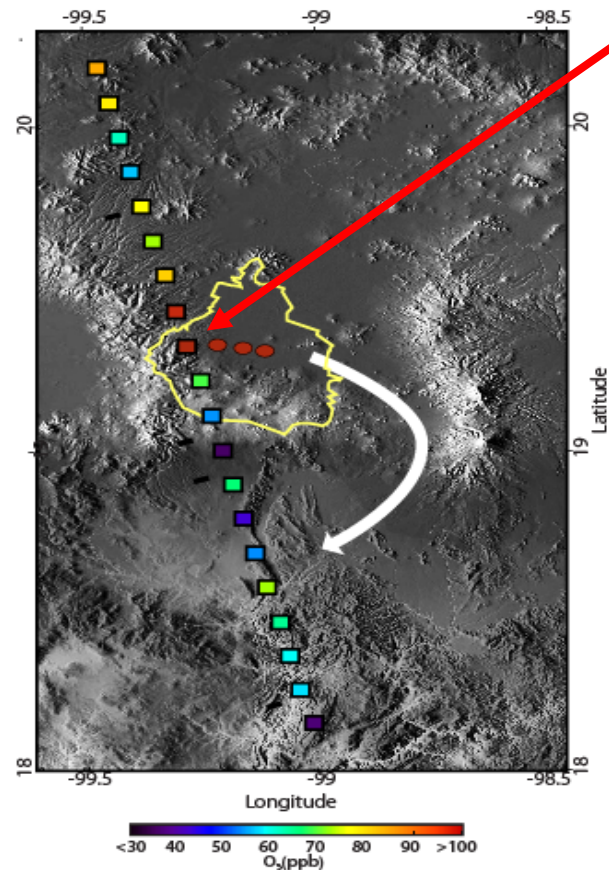
City	Lat	Lon
Bangkok	13.6383	100.304
Beijing	39.8543	116.386
Buenos Aires	-34.7112	-58.9112
Delhi	28.957	77.4496
Dhaka	23.6374	90.1974
Houston	29.7203	-95.2691
Istanbul	40.9605	29.1336
Karachi	24.6877	66.7348
Kolkata	22.5168	88.4081
Lagos	6.57795	3.25456
Los Angeles	34.0724	-118.146
MexicoCity	19.1627	-99.2384
Mumbai	18.8821	72.8437
New York City	40.7045	-73.9673
Paris	48.8499	2.37268
Sao Paulo	-23.5372	-46.6846
Shenzhen	22.3653	113.674
Tokyo	35.5149	139.425

# Mexico City October pollution event

**Megacity Pollution:** The jointly retrieved TES/OMI near-surface ozone product shows very high ozone (~120 ppb) in Mexico City on a day with stable, stagnant air in the boundary layer.

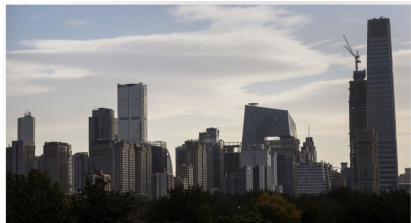
TES carbon monoxide, methanol, & formic acid (ozone precursors) are also elevated, as is the nitrogen reservoir peroxyacetyl nitrate (PAN)

AIRS-OMI O<sub>3</sub>

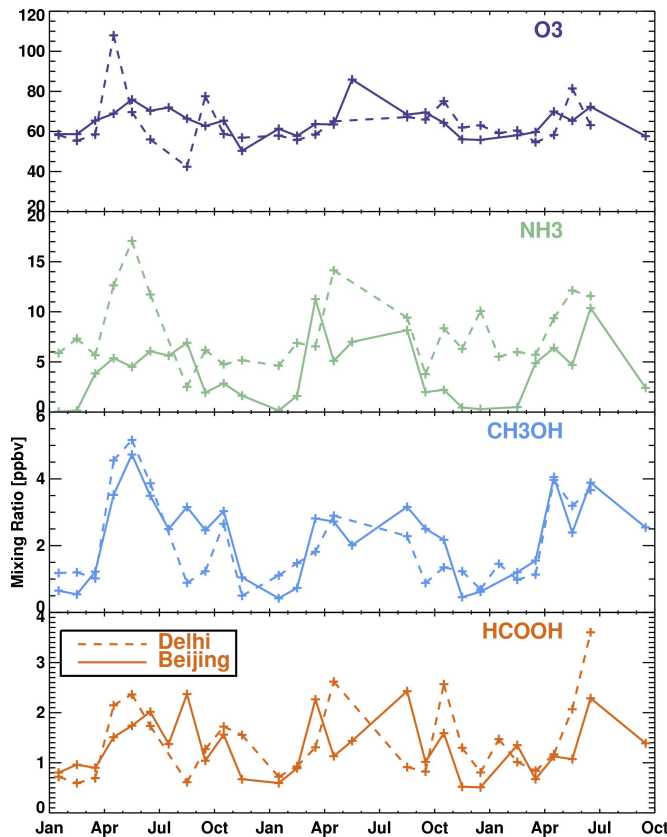


# A Tale of Two Cities

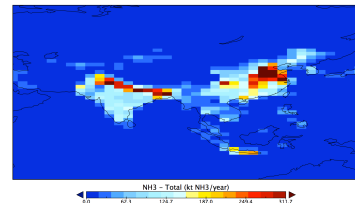
## Beijing



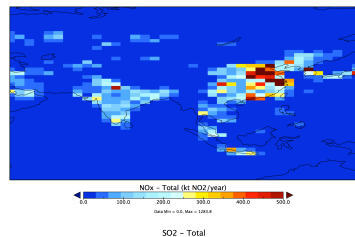
## Delhi



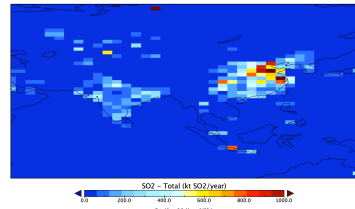
- Similar **O<sub>3</sub>** and **CO** levels
- Why is **NH<sub>3</sub>** different?



**NH<sub>3</sub>**



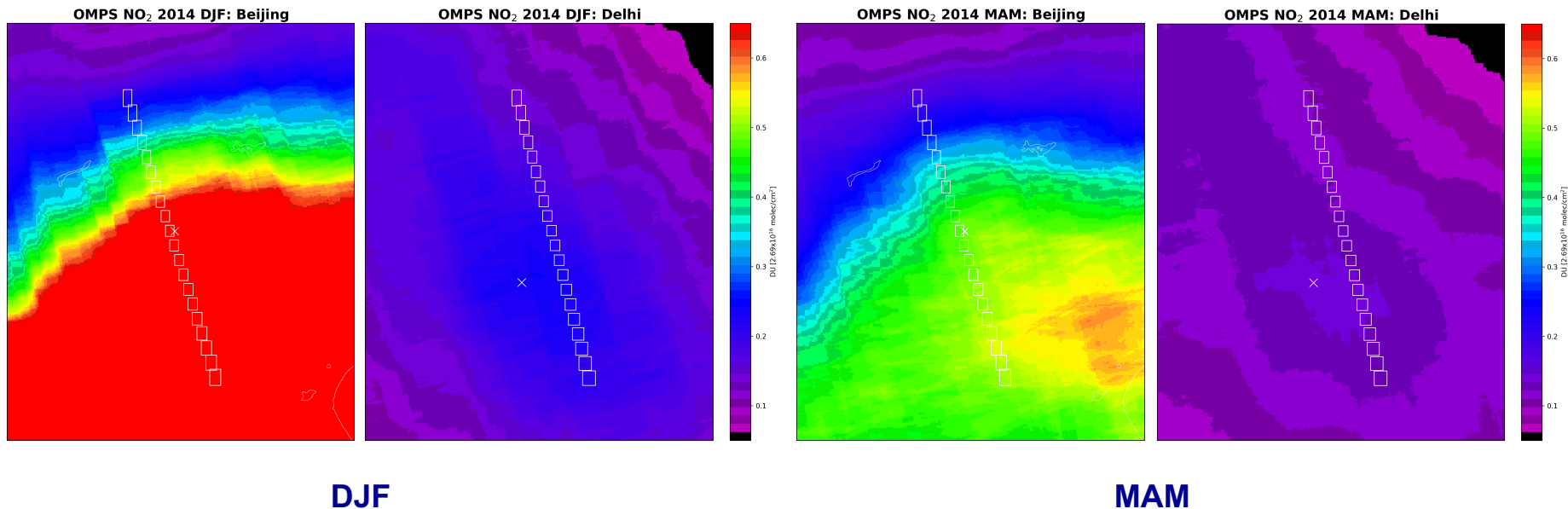
**NO<sub>x</sub>**



**SO<sub>2</sub>**

ECLIPSE v5 emissions

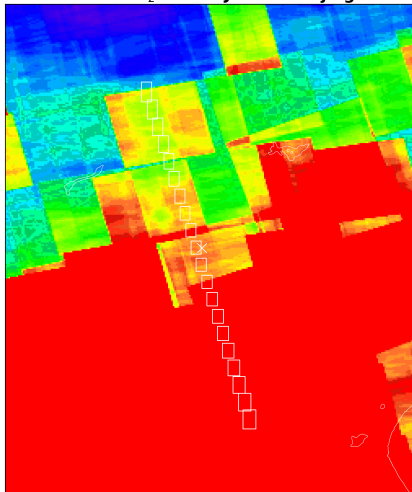
# OMPS NO<sub>2</sub> over Beijing and Delhi



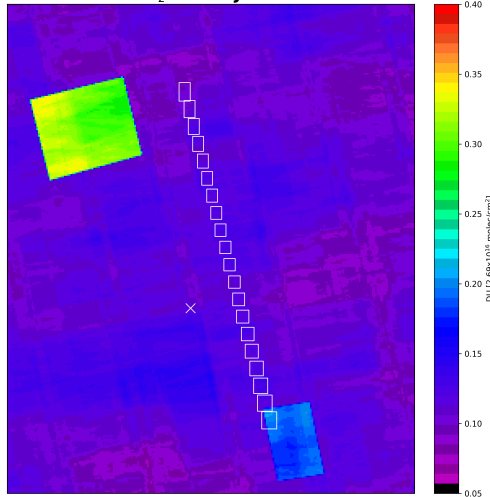
- Much higher NO<sub>2</sub> levels in Beijing
- Greater variability between winter and spring
- But current trend is decrease in Beijing and no increase in Delhi

# SO<sub>2</sub> over Beijing and Delhi

OMPS SO<sub>2</sub> 2014 DJF TRL: Beijing

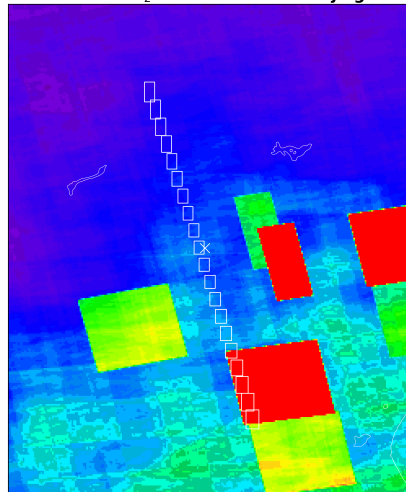


OMPS SO<sub>2</sub> 2014 DJF TRL: Delhi

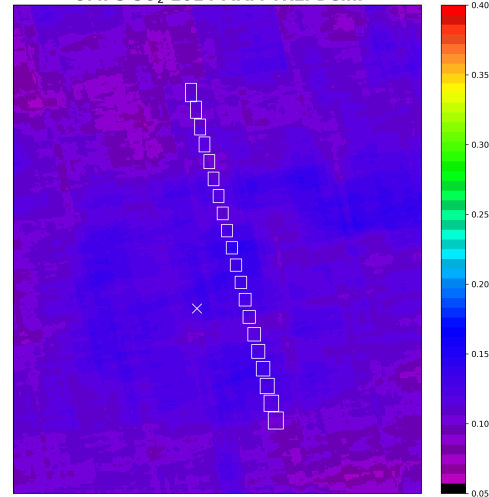


DJF

OMPS SO<sub>2</sub> 2014 MAM TRL: Beijing



OMPS SO<sub>2</sub> 2014 MAM TRL: Delhi



MAM

- Much higher SO<sub>2</sub> levels in Beijing winter
- Some hotspots in Delhi winter and Beijing spring
- Expected trend is decrease in Beijing and increase in Delhi